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Soil Moisture Retrieval in Alpine Area with Synergy of Optical, SAR and Terrain data and Gaussian Process Regression

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Soil moisture is a climate variable that has an important impact on environment and climate system. Many studies exploited remote sensing imagery (especially spaceborne Synthetic Aperture Radar (SAR)) for the retrieval of soil moisture in agricultural areas [1]-[3]. However, most of the available approaches don't perform well in mountain areas and only few studies, specializing on such areas, are reported. Topographic features, heterogeneity in land-cover and presence of vegetation complicate the analysis of data signatures in this complex environment.

The objective of this work is to investigate the synergy of multi-sensor observations for soil moisture retrieval in grassland mountain areas and to discuss its added value. The Kernel method, Gaussian Process Regression (GPR) [4] is used as the retrieval technique. A Synergy of SAR, optical, topographic, in-situ, and ancillary (solar radiation) data is tested. C-band SAR features, i.e. backscattering coefficients and local incidence angles, are acquired by the Envisat ASAR sensor in Wide Swath mode with 150 m resolution. Optical data are represented by daily MODIS surface reflectance (res. 500 m), 250 m resolution normalized vegetation index (NDVI) and leaf area index (LAI) with 1km resolution. Terrain information, such as slope, elevation and aspect are extracted from a 10 m resolution Lidar DEM. The solar data are calculated using the model SPECMAGIC [5]. The top 5-cm volumetric soil moisture measurements are collected daily in eight fixed stations, three located in meadows and four located in pastures. A high resolution (25 m) land-cover map derived from orthophotos is used for the identification of pasture and meadow areas.

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The fusion of different features, i.e. combinations of different data sources was examined.

In the case when radar images are not available an approximate soil moisture estimate can be obtained with the joint knowledge of the land class, vegetation parameters (LAI) and surface reflectance at 2130 nm, which is close to the SWIR water absorption band. For this scenario, corresponding RMSE and correlation coefficient (r) equal 6.03 % Vol. and 0.85 respectively. It should be emphasized that both, surface reflectance and LAI, are derived from optical images. This is as an important observation for the Sentinel 2 applications. Estimation further improves by including solar radiation data. When the information about the global daily irradiance is included as a regressor, soil moisture is estimated with the RMSE and r of 5.23 % Vol. and 0.89 respectively.

If only SAR and terrain data (classified by the land use map) are used in the retrieval, the performance of the GPR is described by the RMSE and r of 7.85 % Vol. and 0.73 respectively. Estimation is just slightly improved by including LAI and is represented by the RMSE of 7.65 % Vol. and r that equals to 0.75. The good performance improvement for SAR retrieval of soil moisture is obtained by including the information about direct solar radiation additionally to the previous case. The RMSE and r for that case are 5.27 % Vol. and 0.89 respectively.

However, the most accurate soil moisture retrieval is obtained with the synergy of SAR, surface reflectance at 2130 nm, terrain features and LAI, and the global daily solar radiation. In this case the RMSE and r are equal to 4.14 % Vol. and 0.93, respectively.

As the next step, the benefit of higher resolution (250 m) LAI maps [6] will be investigated. The main advantage of using the proposed product for soil moisture retrieval, instead of the standard MODIS LAI product, is the improved spatial resolution (from 1 km to 250 m), which is necessary to handle the heterogeneity of Alpine areas. This is an ongoing research and a detailed analysis of these results will be presented during the symposium.

Future work will focus on the increase of the existing dataset with images acquired by different sensors, such as RADARSAT-2, Sentinel 1 and Sentinel 2. Ground measurements from further fixed stations are planned to be included. The possibility of including knowledge of soil moisture obtained from other models, e.g. from hydrological modeling will be considered as well.

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